Saskatchewan Parks and Renewable Resources

Habitat Suitability Criteria for Walleye Spawning and Egg Incubation in Saskatchewan

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Habitat Suitability Criteria for Walleye Spawning and Egg Incubation in Saskatchewan

By

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EXECUTIVE SUMMARY

OBJECTIVE

The lower reach of the Puskwakau River is one of the best known walleye spawning habitats in Saskatchewan.

The objective of the present study was to develop walleye spawning and egg incubation habitat preference curves for water depth, velocity and substrate, using the Puskwakau as a source river. The information will provide a basis from which walleye spawning habitat in Saskatchewan can be evaluated for the purpose of stream rehabilitation and environmental impact assessment.

THE RIVER

Puskwakau River (54°33' 103°34'; map 63L/12) is located in east-central Saskatchewan, about 150 km west of the Saskatchewan-Manitoba border on Highway 106. The river enters Ballantyne Bay of Deschambault Lake on its south shore.

The river is approximately 35 km long and drains about 475 km^2 of predominantly wooded swampy areas. It has an estimated average annual flow of 2.14 m^3/sec and median monthly flows of 1.7, 5.0 and 3.5 m^3/sec, respectively for April, May and June (walleye spawning and egg incubation take place during these months).

METHODS OF ASSESSMENT

A two km section of the lower Puskwakau River between 6 and 8 km from the river mouth was monitored for water velocity, depth and substrate type, as well as egg densities during the following periods: May 13-15, 21-23 (1987); May 10-12, 22-23, May 31-Jun 1 (1988); May 9-11, 16-18 (1989); and May 16-17 (1990). Only a few measurements were taken in 1990 due to near flood-stage flow conditions.

Habitat suitability or preference curves were derived by dividing the relative frequency of habitat used by that of available habitat in the same class interval. Used habitat was defined as a habitat where at least one viable egg was found in the sample.

RESULTS

Spawning Run and Egg Density

Walleye spawning runs in the Puskwakau River usually begin in late April or early May and last for about two weeks. The incubation of eggs during 1987-89 took 15 to 21 days in a temperature range of 8-14°C.

The total egg density (no/m^2) ranged from 0 to 12,917 with an average of 1,005 and a median of 135. Samples with live eggs accounted for 65% of the total number of samples taken. The average density of live eggs was 511; the median was 22 and the maximum was 8,375. Egg densities varied

substantially both from site to site and from year to year. Far fewer eggs, as well as fewer samples with viable eggs were found during 1989 when the flow was very low.

Habitat Availability, Use and Preference

Depth - Water depths in the study reach ranged from 0 to 160 cm. Walleye egg incubation may take place in depths ranging from 7 cm to 94 cm, with an optimum range of 40 - 80 cm.

Velocity - Average water column velocity in the spawning area ranged from near 0 to 1.695 m/sec. Incubation of walleye eggs can take place in velocities as low as 0.03 m/sec to as high as 1.1 m/sec. The preferred velocity range is 0.3 - 1.0 m/sec.

Substrate - The substrate in the study area varied from clay to large boulder. The majority of the bottom was covered with large gravel (size range: 32-64 mm) to small cobble (size range: 64-128 mm). All substrate types can be used for walleye egg incubation. However, large gravel and cobble substrates are preferred.

CONCLUSIONS

Although the three key habitat variables are interrelated, flow velocity appears to have the strongest effect (followed by the substrate) on the dispersion and development of walleye eggs. Therefore, when applying these

curves to assess walleye spawning habitats more weight should perhaps be given to these two variables. Water depth should only be considered as a selection criterion when velocity and substrate criteria are met.

The present study is the first attempt in Saskatchewan to generate walleye spawning and egg incubation habitat suitability curves. These curves provide a set of criteria for assessing walleye spawning habitats and should be more applicable to Saskatchewan situations than those derived from data obtained elsewhere.

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TABLE OF CONTENTS

EXECUTIVE SUMMARY i

ACKNOWLEDGEMENTS v

1. INTRODUCTION 1

2. THE RIVER 1

3. THE STUDY SITE 3

4. METHODS 4

4.1 Habitat Measurement and Egg Sampling 4

4.2 Data Analysis 6

5. RESULTS 7

5.1 Spawning Run and Egg Density 7

5.2 Habitat Availability, Use and Preference . . 9

6. DISCUSSION 15

7. CONCLUSIONS 18

8. RECOMMENDATIONS 18

8.1 General 18

8.2 Specific 19

9. LITERATURE CITED 20

10. APPENDICES. 22

LIST OF TABLES

1. Substrate categorization and coding scheme. 6

2. A comparison of the number of samples taken for each variable among the four sampling years. 6

3. Densities of walleye eggs in the Puskwakau River by sampling year. 9

4. Hydrologic characteristics of the Puskwakau River in the reference transect. 10

5. A comparison of existing habitat suitability curves for walleye spawning and egg incubation with those from the Puskwakau River. 17

LIST OF FIGURES

1. Puskwakau River and its approximate drainage basin. 2

2. Frequency distribution of water depths available to (Fig. 2A) and used by (Fig. 2B) walleye for spawning and egg incubation, Puskwakau River 1987-90. Fig. 2C. A preference curve on water depths for walleye spawning and egg incubation. 11

3. Frequency distribution of flow velocities available to (Fig. 3A) and used by (Fig. 3B) walleye for spawning and egg incubation, Puskwakau River 1987-90. Fig. 3C. A preference curve on flow velocities for walleye spawning and egg incubation. 13

4. Frequency distribution of substrate types available to (Fig. 4A) and used by (Fig. 4B) walleye for spawning and egg incubation, Puskwakau River 1987-90. Fig. 4C. A preference curve on substrate types for walleye spawning and egg incubation. 14

1. INTRODUCTION

Criteria such as habitat preference or suitability curves are generally used for fish habitat assessments. A number of such curves for walleye already exist in the literature (Gaboury 1985, McMahon 1984). However, since these curves were derived from other regions, their application to Saskatchewan situations should be evaluated.

The objective of the present study was to develop walleye spawning and egg incubation habitat preference (suitability) curves for water depth, velocity and substrate, using the Puskwakau as a source river. The information will provide a basis from which walleye spawning habitat in Saskatchewan can be evaluated for the purpose of stream rehabilitation and environmental impact assessment.

2. THE RIVER

The Puskwakau River (54°33' 103°34'; map 63L/12) is located in east-central Saskatchewan, about 150 km west of the Saskatchewan-Manitoba border on Highway 106. It enters Ballantyne Bay of Deschambault Lake on its south shore (Fig. 1).

The river is approximately 35 km long and drains about 475 km^2 of predominantly wooded swampy areas. It has an average annual flow of 2.14 m^3/sec and median monthly flows of 1.7, 5.0 and 3.5 m^3/sec, respectively in April, May and June

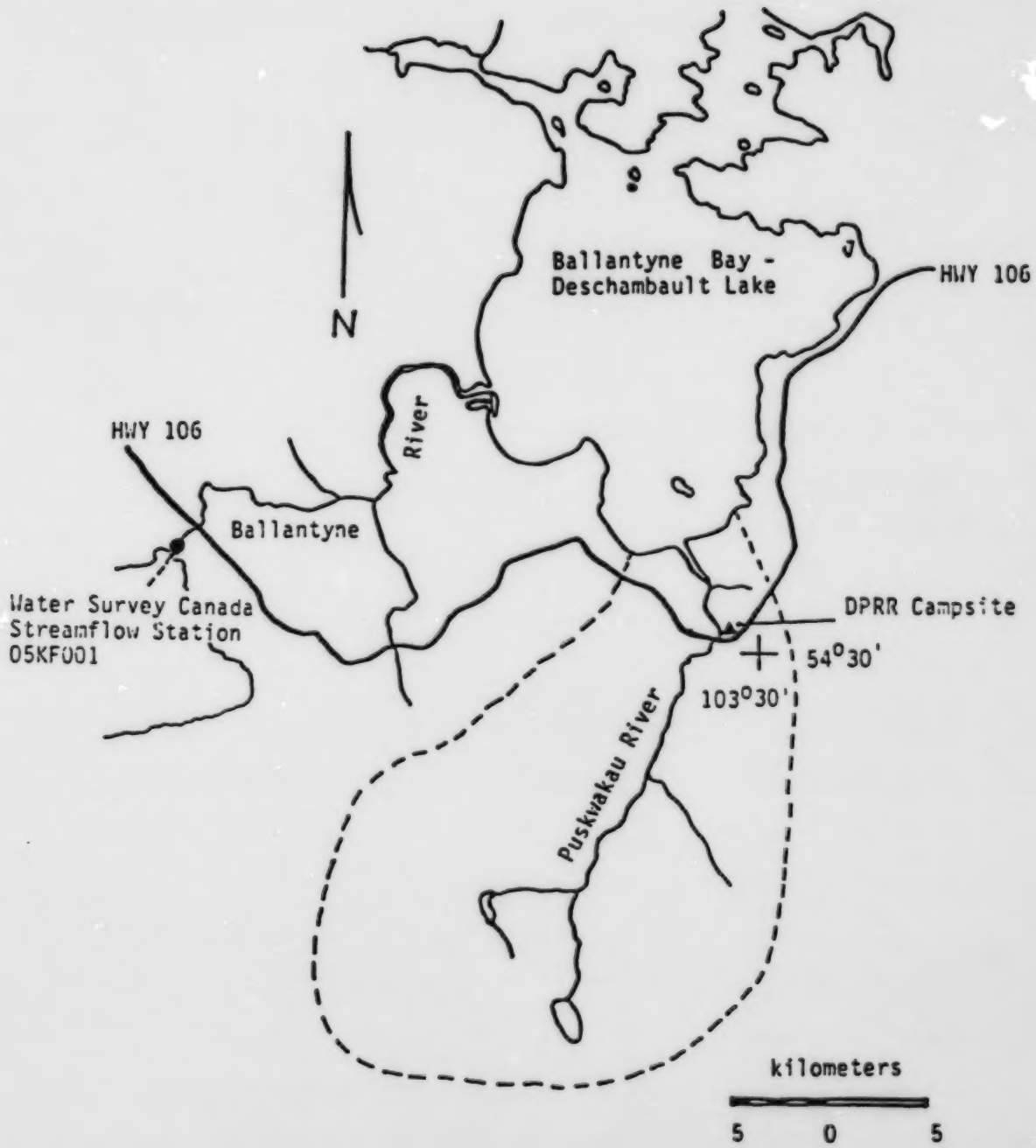

Fig. 1 Puskwakau River and its approximate drainage basin (within the dashed line). Most of the measurements were taken from the two-km reach of the river upstream from the DPRR campsite.

(the three months during which walleye spawning and egg incubation take place). These estimates were based on drainage area ratio with flows recorded at hydrometric station No. 05KF001 at Ballantyne River above Ballantyne Bay (personal communication: A.B. Banga, Saskatchewan Water Corporation 1991) (Fig. 1).

The lower reach of the Puskwakau River is one of the best known walleye spawning habitats in Saskatchewan. Estimated spawning runs in this river average 70,000 to 80,000 walleye. They contribute significantly to maintaining the size of walleye population in Ballantyne Bay of Deschambalt Lake (Wallace 1981).

3. THE STUDY SITE

The study site encompassed a two km section of the lower Puskwakau River upstream from the pool area near the Department of Parks and Renewable Resources campsite (this location was about 6 km from the river mouth at Ballantyne Bay, Fig.1). The study section consisted of six riffle and five pool areas. The first and the longest riffle (about 270 m) had a mean gradient of 0.78 % and average wetted and bankfull (flood stage) widths of 15.15 m and 15.73 m, respectively in May, 1987. This reach of the river is the major spawning site for walleye. Suckers also use it for spawning, but they move farther upstream than do the walleye.

4. METHODS

4.1 Habitat Measurement and Egg Sampling

The study area was monitored for three key habitat features (velocity, depth and substrate type) and egg densities during May 13-15, 21-23, 1987; May 10-12, 22-23, May 31-Jun 1, 1988; May 9-11, 16-18, 1989; and May 16-17, 1990.

A transect system (Platts et al. 1983) was used to quantify available habitat and egg distribution within the study area. Other locations were selected to obtain measurements of habitat (e.g., particularly deep and shallow areas) not adequately represented in the selected transects.

A reference transect was established at a location 10 m downstream of the bridge on HWY 106 in the first riffle area. Location of this reference transect remained the same throughout the study period, whereas those of the other transects and points of measurements were not.

Measurements of current velocity and calculation of discharge follow the procedures outlined in Terzi (1981). A calibrated Pygmy type current meter (no. 625) was used. Mean water column velocity is defined as the arithmetic mean of the velocity distribution in the water column from the bottom to the surface. In waters where depths are less than 75 cm, a single velocity measurement at 0.6 x depth (measured down from the surface) is considered a good estimate of mean column velocity. In deeper waters, two measurements (at 0.2 and 0.8

depth) are taken and the average of the two is the mean column velocity.

Sampling of eggs was done mainly with a Surber sampler (each sample covered an area of 0.93 m^2). In 1989 an air-lift egg sampler was used for sampling deeper areas: usually five samples were taken from one site, each covering an area of 0.010 m^2.

Eggs collected were preserved immediately in a 5 % formaldehyde solution. Later, they were identified (walleye or sucker and their developmental stages) and enumerated with a stereo microscope.

River bed material from where eggs were sampled was also collected. The size for each individual particle was calculated by averaging the measurements of its length, width and thickness. The median of all particle sizes from each sampling site was then obtained. These results were applied to the substrate categorization and coding scheme (Table 1) to determine the dominant substrate type of a site.

Sample size for each variable varies among the four sampling years due to different flow conditions (Table 2). More measurements and samples were obtained in 1989 when velocities and depths were low. However, in 1990 it was only possible to take a few measurements due to high velocity and deep water conditions.

Table 1. Substrate categorization and coding scheme (Fernet and Walder 1986).

Code	Class Name	Size Range (mm)
1	clay/silt	<0.062
2	sand	0.062-2.0
3	small gravel	2-8
4	medium gravel	8-32
5	large gravel	32-64
6	small cobble	64-128
7	large cobble	128-256
8	small boulder	256-762
9	large boulder	>762
10	bedrock	(rock in situ)

Table 2. A comparison of the number of samples taken for each variable among the four sampling years.

Variable	1987	1988	1989	1990	Total
Velocity	114	153	232	20	519
Depth	114	153	242	20	529
Substrate	36	38	49	0	123
Egg	36	37	49	2	124

4.2 Data Analysis

Frequency analysis for measurements of availability and utilization of habitat features, smoothing, as well as basic statistical analyses of the data were done using the Statgraphics computer program (STSC, Inc. 1986). Availability of a habitat feature is determined by extensive field

measurements which should encompass the entire range of the variable (i.e., all the measurements of depths, velocities and substrate types). Used habitat is arbitrarily defined as a sampling site where at least one viable walleye egg was present in the sample.

Habitat preference (suitability) curves were derived by dividing the relative frequency of habitat used by that of available habitat in the same class interval (Bovee 1986; Fernet & Walder 1986; McMahon et al. 1984). The data points were then smoothed by a resistant nonlinear smoothing technique. The habitat is rated on a scale of zero to one with regard to its suitability for walleye spawning and egg incubation. An index of 1 indicates optimum conditions, while a 0 suggests the habitat is least suitable.

5. RESULTS

5.1 Spawning Run and Egg Density

The duration of walleye spawning runs in the Puskwakau River could not be accurately determined from the infrequent field observations conducted in the present study. However, estimates were made using the additional information given by local outfitters. The estimated duration of the spawning run, the developmental stage of walleye eggs when sampled and day-time water temperatures during 1987-89 are as follows:

	1987	1988	1989
Spawning run:			
Begin	April 25	May 5	May 4
Peak	May 1	May 10	May 9
End	May 5	May 15	May 16
Temperature range (°C)	10 -12 (May 13 -23)	8 - 12 (May 11 -31)	12 - 14 (May 9 - 18)
Incubation period (days)	20	21	15
Developmental stages at sampling:			
First sampling	late embryo and tail-free (May 13)	early embryo (morula) (May 11)	early embryo (morula) (May 10)
Second sampling	eyed (May 21); hatching (May 23)	late embryo and tail-free(May 22); hatching completed (May 31)	late embryo and tail-free (May 16-18)

Note: insufficient information for 1990.

The total egg density (no/m^2) ranged from 0 to 12,917 with an average of 1,005 and a median of 135. The average density of live eggs was 511; the median was 22 and the maximum was 8,375. Sixty-five per cent of the total 124 samples taken contained live eggs. Egg densities varied substantially from one year to another. Far fewer eggs were obtained during 1989 when the flow was very low. Also, the number of samples containing live eggs was much lower in 1989 (Table 3).

Table 3. Densities of walleye eggs in the Puskwakau River by sampling year.

Year		1987	1988	1989	1990
Sample size		36	37	49	2
Samples with live eggs: No. (%)		29 (81)	28 (76)	22 (45)	2 (100)
Egg density (no/m^2)					
Average:	Total eggs	315	2,653	283	663
	Live eggs	101	1,500	59	663
Median:	Total eggs	145	678	58	-
	Live eggs	43	75	0	-
Maximum:	Total eggs	1,421	12,917	1,754	702
	Live eggs	904	8,375	565	702

5.2 Habitat Availability, Use and Preference

The three key habitat features in the study area varied considerably during the four years of study. 1989 was an unusually low-flow year, while 1990 was an extremely high-water year. This is illustrated in the measurements obtained from the reference transect (Table 4).

Table 4. Hydrologic characteristics of the Puskwakau River in the reference transect.

Year (date)	1987 (May 13)	1988 (May 10)	1989 (May 9)	1990 (May 16)
Flow (m^3/sec)	4.264	3.616	0.348	9.014
Mean velocity (m/sec)	0.730	0.562	0.192	0.525*
Mean depth (m)	0.38	0.42	0.15	1.01
Wetted width (m)	15.3	15.4	11.9	17.0

*Underestimate due to insufficient measurements of high flow velocities.

Measurements obtained in each year were combined to give a broader range for each habitat feature and more data points for frequency analyses (Appendix 1).

Depth - The frequency distribution of available water depths in the study area is shown in Fig. 2a. The measured depths ranged from 0 to 160 cm with a mean of 39 cm, a median of 35 cm and a mode of 35 cm.

Depths used by walleye for egg incubation ranged from 7 cm to 94 cm, with a mean of 41 cm, a median of 40 cm and a mode between 30 and 40 cm (Fig. 2b).

The depth preference (suitability) curve developed from available and used depths (Fig. 2c), indicates that the optimum or preferred depth range for walleye egg incubation is 40-80 cm.

Velocity - Measurements of average water column velocity ranged from near 0 to 1.695 m/sec with a mean of

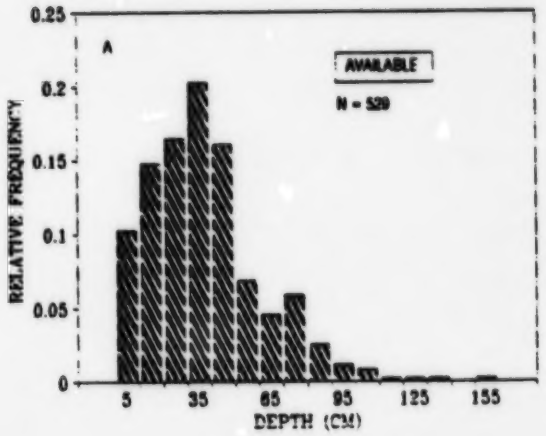

Fig. 2A Frequency distribution of water depths available to walleye for spawning and egg incubation, Puskwakau River 1987-90.

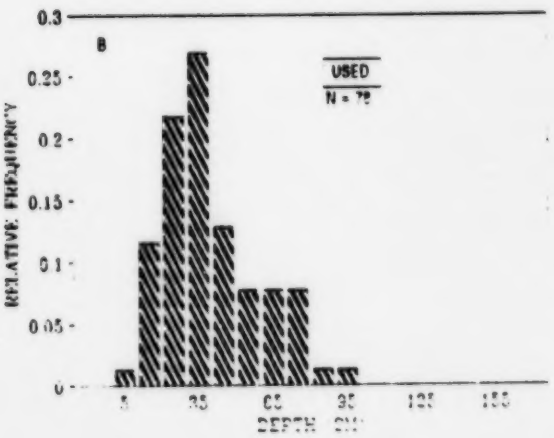

Fig. 2B Frequency distribution of water depths used by walleye for spawning and egg incubation, Puskwakau River 1987-90.

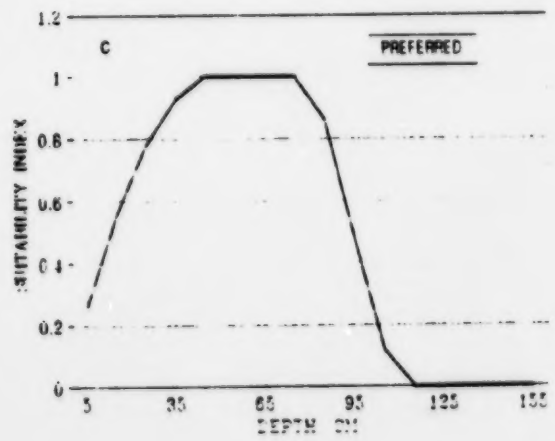

Fig. 2C A preference curve on water depths for walleye spawning and egg incubation (see text and Appendix 1a for explanation).

0.357 m/sec, a median of 0.234 m/sec and a mode of 0.03 m/sec. Most of the low values were obtained in 1989, whereas high values were from 1990 measurements (Fig.3a).

The curve for velocity utilization (Fig.3b) suggests that incubation of walleye eggs can take place in areas with flows as low as 0.03 m/sec to as high as 1.1 m/sec. Measurements of velocity were biased toward low values, because more measurements were taken in 1989 when the flow was unusually low.

The velocity preference curve (Fig.3c) indicates that the range of optimum water velocities for walleye egg incubation is 0.3-1.0 m/sec. Suitability drops rapidly when the velocity is greater than 1.1 m/sec; on the other hand, conditions are still quite suitable (index> 0.5) for egg incubation when the velocity is as low as 0.1 m/sec.

Substrate - The type of substrate in the study area varied from clay to large boulders, with majority of the bottom covered with large gravel to small cobble (substrate codes 5 and 6; Fig.4a).

All substrate types were used for walleye egg incubation (Fig. 4b). Particle sizes ranging from medium-sized gravel to small cobble were used most frequently.

The substrate preference curve (Fig. 4c) indicates that large gravel and cobble substrates (codes 5,6,7) are most suitable for egg incubation.

A significant positive correlation ($p<0.01$) exists

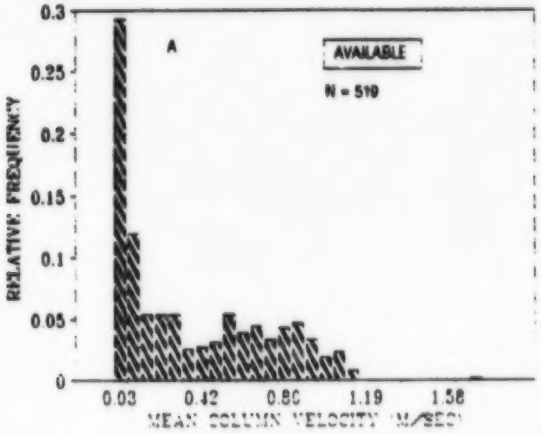

Fig. 3A Frequency distribution of flow velocities available to walleye for spawning and egg incubation, Puskwakau River 1987-90.

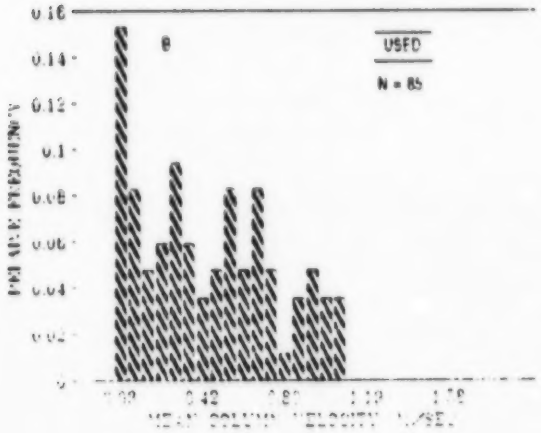

Fig. 3B Frequency distribution of flow velocities used by walleye for spawning and egg incubation, Puskwakau River 1987-90.

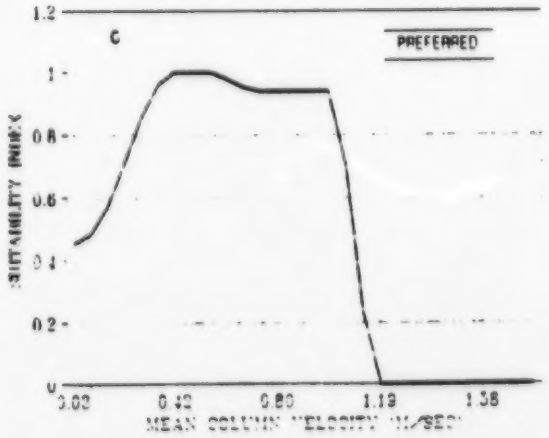

Fig. 3C A preference curve on flow velocities for walleye spawning and egg incubation (see text and Appendix 1b for explanation).

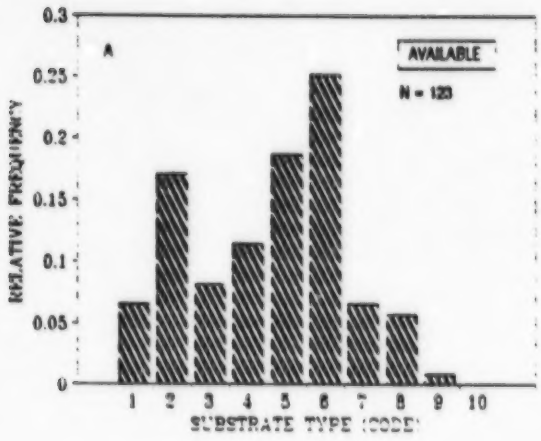

Fig. 4A Frequency distribution of substrate types available to walleye for spawning and egg incubation, Puskwakau River 1987-90.

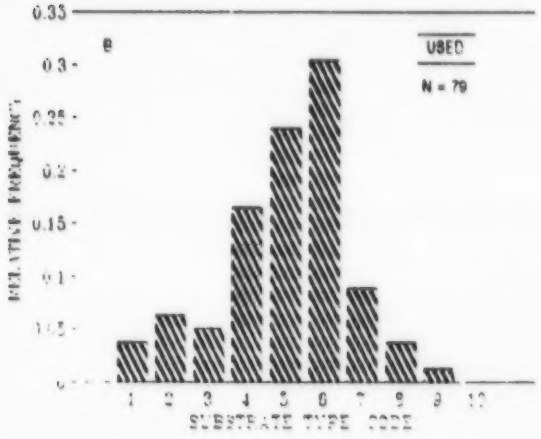

Fig. 4B Frequency distribution of substrate types used by walleye for spawning and egg incubation, Puskwakau River 1987-90.

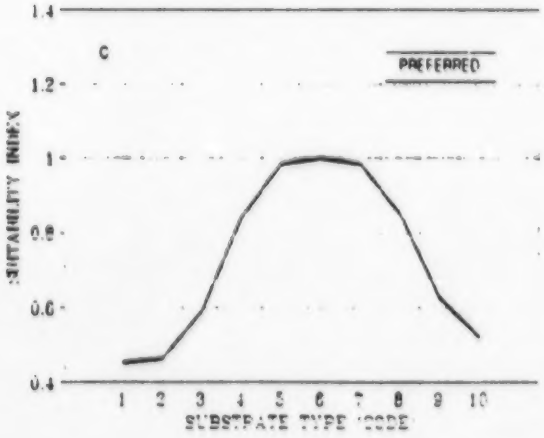

Fig. 4C A preference curve on substrate types for walleye spawning and egg incubation (see text and appendix 1c for explanation).

between the presence of live eggs and the velocity and substrate size, but a negative correlation ($p<0.01$) was found between the presence of live eggs and the depth.

The correlation between egg density and velocity is highly significant ($p<0.002$). Substrate size is also significantly correlated ($p<0.03$) with egg density. However, no significant correlation was found between egg density and depth.

The above analysis suggests that although the presence or absence of live eggs and their densities are determined by the combined effect of the three key habitat variables, velocity appears to be most important, followed by substrate size. Depth appears to be least important.

6. DISCUSSION

A number of habitat use and selection curves for walleye spawning and egg incubation already exist in the literature (e.g. Gaboury 1985; McMahon, Terrell & Nelson 1984). However, it is commonly recognized that habitat suitability curves derived from one location may not be directly applicable to another. Therefore, there is a need to have more curves generated under a wide range of habitat conditions (Bovee 1982; Parsons & Hubert 1988). The present study is the first attempt in Saskatchewan to generate walleye spawning and egg incubation habitat suitability curves, using one of the best known walleye spawning habitats in the

province. These curves should be more applicable to Saskatchewan situations than those derived from data obtained elsewhere.

Habitat suitability curves for depth in the literature have an overall range of 15-198 cm and optimum values of 40-153 cm (Table 5). By comparison, the depth suitability curve obtained from the Puskwakau has a narrower range in utilization and optimum values because it is a smaller river and has fewer deepwater areas. Furthermore, sampling was biased toward shallower areas due to low water conditions in 1989.

With respect to velocity, the ranges of utilization for all three curves are similar (Table 5). But, walleye in the Puskwakau were able to use areas with lower water velocities, with the optimum values extending from about 1 m/sec down to 0.3 m/sec.

Suitability curves for substrate categories from other locations are similar to that from the Puskwakau River (Table 5). This implies that walleye select similar substrate for spawning and egg incubation regardless of localities. The best substrate for walleye spawning and egg incubation appears to be a mixture of gravel and cobble.

The habitat suitability curves from the Puskwakau River extend the lower limits of optimum values for water depth and velocity by providing measurements in shallow and slow flow areas. The similarity among existing suitability

curves suggests that the curves generated from the Puskwakau data have a broader range of application than the original data set suggests. Therefore, they, together with the existing suitability curves, may provide some criteria for the evaluation and rehabilitation of walleye spawning habitat in Saskatchewan or other locations.

Table 5. A comparison of existing habitat suitability curves for walleye spawning and egg incubation with those from the Puskwakau River (values are approximations obtained from the original curves).

Variable	Range	Optimum	Location and reference
Depth(cm)	7-94	40-80	Puskwakau R. present study
	15-150	40-90	Valley R.,Manitoba. Gaboury (1985)
	30-198	76-153	Yellowstone R., Montana and Missouri R.,S.Dakota, Nebraska and Iowa. McMahon (1984)
Velocity (m/sec)	0.03-1.13	0.32-1.03	Puskwakau R. present study
	0 - 1.4	0.6 -1.1	Valley R., Manitoba. Gaboury (1985)
	0 - 1.05	0.75-0.9	Yellowstone R., Montana. McMahon (1984)
Substrate (code)	1-9	5-7	Puskwakau R. present study
	3-7 (1-9)*	5-6 (3-7)*	Valley R., Manitoba. Gaboury (1985)
	3-7 (1-9)*	5-6 (3-7)*	Missouri R. and Minnisota. McMahon (1984)

*converted to the category codes used in this study.

7. CONCLUSIONS

The habitat suitability curves for walleye spawning and egg incubation derived from the Puskwakau River have extended the existing lower limits of optimum values for water depth and velocity by providing measurements from shallow and low flow velocity areas. These are the first set of habitat suitability curves generated from Saskatchewan data. They provide a set of criteria for assessing walleye spawning habitats and should be more applicable to Saskatchewan situations than those derived from data obtained elsewhere. However, more field data should be obtained from a wide range of stream conditions to test and extend the applicability of these suitability curves.

Although the three key habitat variables are interrelated, flow velocity appears to have the strongest effect (followed by the substrate) on the dispersion and development of walleye eggs. Therefore, when applying these curves to assess walleye spawning habitats more weight should perhaps be given to these two variables. Water depth should only be considered as a selection criterion when velocity and substrate criteria are met.

8. RECOMMENDATIONS

8.1 General

1. Use the habitat suitability curves generated from

the Puskwakau River as a baseline information for the evaluation/rehabilitation of walleye spawning and egg incubation habitats in Saskatchewan.

2. Obtain more field data from a wide range of stream conditions to test and extend the applicability of the habitat suitability curves.

8.2 Specific to the Puskwakau River and Deschambault Lake

1. In view of the importance of the walleye runs in the Puskwakau River to maintaining the walleye population in Ballantyne Bay of Deschambault Lake, angling on the river during spawning run should remain closed.

2. Conduct a study on Deschambault Lake to investigate walleye spawning success on the Puskwakau River and year class strength of walleye in Ballantyne Bay.

3. The natural condition of the Puskwakau watershed should be preserved to maintain the hydrologic and morphologic characteristics of the river which are vital to walleye spawning and their egg development. Similar considerations should be given to other major walleye spawning habitats of Deschambault and other lakes in the Province.

9. LITERATURE CITED

Bovee, K.D. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. U.S. Fish and Wildlife Service Biological Service Program FWS/OBS-82/26.

_____. 1986. Development and evaluation of habitat suitability criteria for use in the instream flow incremental methodology. U.S. Fish and Wildlife Service Biological Report 86(7).

Fernet, D.A. and G.L. Walder. 1986. The development of habitat suitability criteria for use with the instream flow incremental methodology - A manual for the Province of Alberta. Prepared for: Habitat Branch Fish and Wildlife Division. Edmonton, Alberta. Environmental Management Associates, Calgary, Alberta.

Gaboury, M. 1985. The effects of land use changes and activities on walleye reproduction success in the Valley River, Manitoba. In D. Baccante (ed.). "Walleye and Tourism: Future Management Strategies". Proceedings of a conference sponsored by the Northwestern Ontario Chapter of the American Fisheries Society. Sept. 18-21, 1984. Quetico Centre, Ontario. p. 24-40.

McMahon, T.E., J.W. Terrell and P.C. Nelson. 1984. Habitat suitability information: Walleye. U.S. Fish and Wildlife Service Biological Service Program FWS/OBS-82/10.56.

Parsons, B.G.M. and W.A. Hubert. 1988. Influence of habitat availability on spawning site selection by kokanees in streams. North American Journal of Fisheries Management 8:426-431.

Platts, W.S., W.F. Megahan and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Forest Service Intermountain Forest and Range Experimental Station, Ogden, Unit 84401 General Technical Report INT-138.

STSC, Inc. 1986. Statgraphics User's Guide. Rockville, Maryland.

Terzi, R.A. 1981. Hydrometric field manual - Measurement of streamflow. Environment Canada Inland Waters Directorate Water Resources Branch, Ottawa.

Wallace, R.G. 1981. The walleye fisheries of Puskwakau River and Ballantyne Bay of Deschambault Lake, Saskatchewan. Dept. Northern Saskatchewan Fisheries Technical Report # 6.

Appendix 1a. **Frequency distribution of availability and use for water depths and calculated suitability index for walleye spawning and egg incubation, Puskwakau River.**

Class interval (cm)	Midpoint (cm)	Frequency (used)	Frequency (available)	Preferred (ratios#)	Smoothed* (ratios)	Suitability** index
0 - 10	5	0.013	0.102	0.125	0.295	0.26
10 - 20	15	0.115	0.147	0.783	0.624	0.55
20 - 30	25	0.218	0.164	1.325	0.877	0.78
30 - 40	35	0.269	0.202	1.331	1.047	0.93
40 - 50	45	0.128	0.161	0.798	1.130	1.00
50 - 60	55	0.077	0.068	1.130	1.130	1.00
60 - 70	65	0.077	0.045	1.695	1.130	1.00
70 - 80	75	0.077	0.059	1.312	1.130	1.00
80 - 90	85	0.013	0.025	0.521	0.977	0.86
90 - 100	95	0.013	0.011	1.129	0.543	0.48
100 - 110	105	0.000	0.008	0.000	0.130	0.12
110 - 120	115	0.000	0.002	0.000	0.000	0.00
120 - 130	125	0.000	0.002	0.000	0.000	0.00
130 - 140	135	0.000	0.002	0.000	0.000	0.00
140 - 150	145	0.000	0.000	0.000	0.000	0.00
150 - 160	155	0.000	0.002	0.000	0.000	0.00

 # Frequency (used)/Frequency (available)

** 5RSSH resistant nonlinear smoothing*

*** obtained by dividing each smoothed ratio by the maximum value of 1.130*

Appendix 1b. **Frequency distribution of availability and use for flow velocities and calculated suitability index for walleye spawning and egg incubation, Puskwakau River.**

Class interval (m/sec)	Midpoint (m/sec)	Frequency (used)	Frequency (available)	Preferred (ratios#)	Smoothed* (ratios)	Suitability** index
0.000-0.064	0.032	0.153	0.293	0.522	0.690	0.452
0.064-0.129	0.096	0.082	0.119	0.690	0.736	0.482
0.129-0.193	0.161	0.047	0.054	0.873	0.881	0.577
0.193-0.257	0.225	0.059	0.054	1.090	1.090	0.714
0.257-0.321	0.289	0.094	0.054	1.744	1.309	0.857
0.321-0.386	0.354	0.059	0.025	2.347	1.473	0.964
0.386-0.450	0.418	0.035	0.027	1.309	1.527	1.000
0.450-0.514	0.482	0.047	0.031	1.528	1.527	1.000
0.514-0.579	0.546	0.082	0.054	1.527	1.527	1.000
0.579-0.643	0.611	0.047	0.039	1.222	1.505	0.985
0.643-0.707	0.675	0.082	0.044	1.859	1.460	0.956
0.707-0.771	0.739	0.047	0.033	1.438	1.438	0.941
0.771-0.836	0.804	0.012	0.042	0.278	1.438	0.941
0.836-0.900	0.868	0.035	0.046	0.763	1.438	0.941
0.900-0.964	0.932	0.047	0.033	1.438	1.438	0.941
0.964-1.029	0.996	0.035	0.019	1.832	1.438	0.941
1.029-1.093	1.061	0.035	0.023	1.527	1.078	0.706
1.093-1.157	1.125	0.000	0.008	0.000	0.359	0.235
1.157-1.221	1.189	0.000	0.000	0.000	0.000	0.000

 # Frequency(used)/Frequency(available)

** 5RSSH resistant nonlinear smoothing*

*** obtained by dividing each smoothed ratio by the maximum value of 1.527*

Appendix 1c. **Frequency distribution of availability and use for substrate types and calculated suitability index for walleye spawning and egg incubation, Puskwakau River.**

Substrate code	Frequency (used)	Frequency (available)	preferred (ratios#)	Smoothed* (ratios)	Suitability** index
1	0.038	0.065	0.584	0.584	0.454
2	0.063	0.171	0.371	0.594	0.462
3	0.051	0.081	0.622	0.759	0.590
4	0.165	0.114	1.446	1.080	0.840
5	0.241	0.187	1.286	1.266	0.984
6	0.304	0.252	1.205	1.286	1.000
7	0.089	0.065	1.362	1.266	0.984
8	0.038	0.057	0.668	1.091	0.848
9	0.013	0.008	1.562	0.802	0.624
10	0.000	0.000	0.000	0.668	0.519

 # Frequency(used)/frequency(available)

** 5RSSH resistant nonlinear smoothing*

*** obtained by dividing each smoothed ratio by the maximum value of 1.266*